

## SOLDER MASK REMOVAL METHOD

## FIELD OF THE INVENTION

[0001] The present invention relates to printed circuit board fabrication generally, and more specifically to failure analysis methods that require removal of solder masks.

## BACKGROUND

5 [0002] A solder mask (also called "solder resist") is a coating used to protect (mask) certain areas of a printed circuit board during the soldering of connections to the circuit board. Because the solder mask covers most of the circuit board, it protects the circuitry and provides electrical insulation. Thus, only a small area of the circuit is exposed to solder. Therefore, as less  
10 solder is used, the likelihood of solder bridging over the circuit lines and other features is reduced. Also, there is less chance that contaminants will be transferred into the solder container from the circuit board. Also, the solder mask reduces dendritic growth of the copper elements on the circuit board. (The solder mask also isolates the PCB circuit traces from the external environment.)

15 [0003] A printed circuit board may be observed to fail during testing. Failure analysis engineers must make a determination of the reason for the failure. Because the failure may be the result of a short or open circuit in a metal trace on a layer of the printed circuit board beneath the solder mask, it may be necessary to remove the solder mask to complete the failure analysis.

[0004] A known technique for solder mask removal used by failure analysis engineers is  
20 polishing the solder mask until the defect is revealed. However, using the polishing method, it is very easy to cause artifacts and damage the circuit trace. Thus, it becomes difficult or impossible to determine whether a defect observed in the underlying circuit trace was present before the polishing, or caused by the polishing.

[0005] Other conventional techniques for solder mask removal include milling, grinding,  
25 microblasting, and chemical stripping.

[0006] Milling involves use of sharp cutters, so precision depth control is required. The milling system requires a microscope. The carbide cutters typically used are so sharp they will tend to pull into the coating and may penetrate into the board surface.

[0007] Grinding involves the use of a knife, scraper or pick by a skilled technician. No special setup is needed, but operator fatigue can be a disadvantage.

[0008] Microblasting involves propelling an abrasive material at the solder mask. The abrasive material blasts away the coating. This creates substantial friction and static charges. For circuit boards with static sensitive devices, the tool must be designed to eliminate potential ESD damage. Significant preparation time including masking is often needed. A thorough cleaning is required to flush away any blasting material from the circuit board. Operator skill and training are also required.

[0009] Chemical stripping involves application of a material like a paint stripper to the solder mask. Because the stripper is liquid, it is often hard to control. The most common chemical strippers can deteriorate the base material beneath the solder mask if exposed to the stripper for too long a time.

[0010] A failure analysis method that does not cause further damage to the underlying circuitry of the printed circuit board is desired.

## SUMMARY OF THE INVENTION

[0011] A printed circuit board having a circuit trace thereon and a solder mask over the circuit trace is provided. The solder mask is removed from the printed circuit board using an ultra violet laser, to expose the circuit trace without damaging the circuit trace. A failure analysis is performed on the circuit trace of the printed circuit board.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. 1 is a flow chart diagram of an exemplary method according to the present invention.

[0013] FIG. 2 is an enlarged photograph showing a metal circuit trace on a printed circuit board exposed by an exemplary method described herein.

[0014] FIG. 3 is an enlarged detail of FIG. 2, showing an open circuit.

## DETAILED DESCRIPTION

[0015] This description of the exemplary embodiments is intended to be read in connection with the accompanying drawings, which are to be considered part of the entire written description. In the description, relative terms such as "lower," "upper," "horizontal,"

“vertical,” “above,” “below,” “up,” “down,” “top” and “bottom” as well as derivative thereof (e.g., “horizontally,” “downwardly,” “upwardly,” etc.) should be construed to refer to the orientation as then described. These relative terms are for convenience of description and do not require that the apparatus be constructed or operated in a particular orientation.

5 [0016] FIG. 1 is a flow chart of an exemplary method according to one embodiment of the present invention.

[0017] At step 100, a printed circuit board processing operation is performed. For example, an organic core substrate of a glass-reinforced epoxy resin having a circuit trace thereon may be processed by providing an insulation layer over the circuit trace, a second circuit  
10 trace on the insulation layer, a second insulation layer on the second circuit trace, and so on. The printed circuit board may have any desired number of circuit traces, with insulation layers therebetween. The circuit traces on adjacent layers are connected using vias, which are formed in the insulation layer between the interconnected circuit traces. The printed circuit board may be, for example, a card for a personal computer, or the substrate of a ball grid array package.

15 [0018] At step 102, a metal circuit trace is formed on the outer surface of the outermost insulation layer, and interconnections are formed to connect to one or more of the circuit traces between the core and the outer circuit trace.

[0019] At step 104, a solder mask is applied above the circuit trace. The solder mask may be formed of a liquid or dry film type, for example. Liquid solder resist masks may be  
20 applied by screen printing or the like. The solder mask may be formed of an organic compound such as an epoxy resin. For example, the solder resist may be a thermosetting resin that is cured by heating after it is deposited. Solder resist materials having C-C, C-O, C-H and/or C-Si bonds may be used. A solder mask may be formed using the method of U.S. Patent No. 5,626,774 or U.S. Patent No. 6,346,678, both of which are expressly incorporated by reference herein in their  
25 entireties.

[0020] In some embodiments, the solder mask comprises a film selected from the group consisting of polyimide and cyanate ester resins and a dual solution photo-curing type material containing an unsaturated resin that includes carboxylic acid and a polyepoxy compound. The technique described herein may be applied to remove any type of solder mask.

30 [0021] Once the solder mask is applied, then solder balls can be applied to the printed circuit board, in the openings in the solder mask.

[0022] At step 106, the printed circuit board is tested. The tests may be of any type appropriate for the circuitry and packages included in or on the printed circuit board.

[0023] At step 108, the printed circuit board is identified as having a defect, and as being a candidate for failure analysis.

5 [0024] At step 110, the solder mask is removed using an ultraviolet (UV) laser, without damaging the metal circuit trace under the solder mask.

[0025] FIG. 2 shows an example of a circuit trace 202 on a printed circuit board 200, from which the solder mask has been removed. FIG. 3 is an enlarged detail of FIG. 2, showing an open circuit 204 in the circuit trace 202. The circuit trace 202 is essentially undisturbed, so  
10 that the open circuit 204 shown in FIG. 3 is clearly identifiable, and attributable to a defect that was present when the testing was failed. That is, there is no confusion as to whether the defect 204 was caused by the UV laser used to remove the solder mask.

[0026] In one example, using the laser removal technique, a 30  $\mu\text{m}$  organic solder mask was removed from Part ID : TMB911, which includes a substrate sold by Kyocera, assembled by  
15 Advanced Semiconductor Engineering Inc. of Taiwan. The laser was a "New Wave Research QuikLaze", having a wavelength of 355nm, Pulse width of 6ns, Pulse frequency of 20Hz, and 0.6mJ Power using the low energy setting (and about 200 mJ at the QuikLaze setting). A 35  $\mu\text{m}$  circuit trace was thus exposed.

[0027] At step 112, failure analysis is performed on the metal trace of the printed circuit  
20 board. The type of failure analysis operation depends on the nature of the defect. For example, in the circuit trace 202 shown in FIGS. 2 and 3, the defect can be detected visually. In other instances, where the defect is not readily visible, electrical testing or scanning electron microscope (SEM) inspection, or other inspection technique may be used.

[0028] UV laser light as described above can decompose organic materials with C-C,  
25 C-O, C-H and/or C-Si bonds. The ultraviolet laser may have a wavelength of from about 3 nanometers to about 400 nanometers. An exemplary ultraviolet laser is a yttrium aluminum garnet (YAG) laser having a wavelength of 355 nanometers or 266 nanometers.

[0029] There are four main laser types : Solid-state lasers, Gas lasers, Excimer lasers, and Dye lasers. Ultraviolet (UV) Radiation includes electromagnetic radiation with wavelengths  
30 between soft X rays and visible violet light, often broken down into UV-A (315-400 nm), UV-B (280-315 nm), and UV-C (100-280 nm). All the four main types of laser can produce UV laser.

[0030] (1) Solid state laser

[0031] A solid state laser is a laser in which the active medium is in solid state (usually not including semiconductor lasers).

[0032] An example is the all solid-state Deep UV Laser source "PAL/PRO - UV <sup>TM</sup>"

5 laser system sold by Light Age, Inc. of Somerset, NJ, which produces ultra narrowband light at. 248 nm, 193 nm, and Other UV wavelengths. A ruby laser was the first laser type. The ruby laser is a solid state laser which use a crystal of sapphire (aluminum oxide) containing trace amounts of chromium oxide as an active medium. A Yttrium Aluminum Garnet (YAGP) laser uses a synthetic crystal, YAG. An Nd:YAG Laser is a solid-state laser in which Neodymium  
10 doped YAG is used as a laser active medium, to produce 1064 [nm] wavelength.

[0033] Semiconductor Laser or diode laser

[0034] A semiconductor laser is a type of laser which produces its output from semiconductor materials such as GaAs.

[0035] (2) An excimer laser is a gas laser which emits in the UV spectrum. The active  
15 medium is an "Excited Dimer" which does not have a stable ground state. Table 1 lists wave lengths of the more common laser types

Table 1

Laser Type	Media	Wave Length (s)	Nanometers
Excimer Gas Lasers	Argon Fluoride	(UV)	193 nm
	Krypton chloride	(UV)	222 nm
	Krypton Fluoride	(UV)	248 nm
	Xenon Chloride	(UV)	308 nm
	Xenon Fluoride	(UV)	351 nm
Gas Lasers	Nitrogen	(UV)	337 nm
	Helium Cadmium	(UV)	325 nm
	Helium Cadmium	(Violet)	441 nm
Dye Lasers	Rhodamine 6G	(VIS)	570-650 nm

[0036] (3) A gas laser is a laser in which the active medium is a gas. The gas can be  
20 composed of molecules (like CO<sub>2</sub>), Atoms (like He-Ne), or ions (like Ar<sup>+</sup>). Table 2 lists wavelengths of several gas lasers.

Table 2

Laser Type	Wavelength (nm)
<b>Argon fluoride (UV)</b>	<b>193</b>
<b>Krypton Fluoride (UV)</b>	<b>248</b>
<b>Nitrogen (UV)</b>	<b>337</b>
Argon (blue)	488
Argon (green)	514
Helium neon (green)	543
Helium neon (red)	633
Rhodamine 6G dye (tunable)	570-650
Ruby (CrAlO <sub>3</sub> ) (red)	694
Nd: YAG (NIR)	1064
Carbon Dioxide (FIR)	10600

[0037] (4) A dye laser is a laser using a dye solution as its active medium. Its output is a short pulse of broad spectral content and its achievable gain is high. Table 3 compares wavelengths of a frequency doubled nitrogen pumped dye laser with lasers of the other types.

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Table 3

Laser Type	Freq doubled Argon ion	KrF Excimer	Fourth harmonic Nd:YAG	Freq doubled N <sub>2</sub> pumped dye	New Photon Systems DUV lasers
<b>Wavelengths, nm</b>	228, 234, 238, 244, 248, 257	248	266	200-300 tunable	224,248,260, 270,280

[0038] If the defect is not detected in the circuit trace immediately beneath the solder mask, following removal of the solder mask by UV laser, another type of laser can be used to remove one of the underlying layers for additional failure analysis. A green wavelength laser (such as 532 nm) can be applied to remove metal such as Cu and Al.

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[0039] Although the invention has been described in terms of exemplary embodiments, it is not limited thereto. Rather, the appended claims should be construed broadly, to include other variants and embodiments of the invention, which may be made by those skilled in the art without departing from the scope and range of equivalents of the invention.